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Sound Waves

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Research

Japan Lashed by Powerful Earthquake, Devastating Tsunami

By Helen Gibbons

The magnitude 9.0 earthquake that struck Japan on March 11, 2011, was unprecedented in the modern history of Japan, according to scientists at the U.S. Geological Survey (USGS). “This was a massive earthquake,” said USGS research geophysicist **Bill Ellsworth**, “one of the largest earthquakes that we have ever recorded” and the largest instrumentally recorded earthquake ever to hit Japan.

The earthquake occurred on a fault that forms the boundary between the Pacific and North American tectonic plates. In this region, the Pacific plate is sliding (being “subducted”) westward beneath the North American plate, on which northern Japan sits, at a rate of about 80 mm (3 inches) per year, beginning its westward descent at the Japan Trench. The earthquake’s epicenter—the location on the Earth’s surface directly above where rupture began—lies about 140 km (90 mi) west of the Japan Trench and about 130 km (80 mi) east of the city of Sendai on Honshu, Japan’s main island.

Preliminary estimates indicate that a large area of the fault ruptured during the earthquake: about 400 km (250 mi) long by 150 km (90 mi) wide, with its long dimension parallel to the coast. (Download Earthquake Summary Poster at **http://earthquake.usgs.gov/earthquakes/eqarchives/poster/2011/20110311.php**.) Scientists estimate that tens of meters of slip took place along the rupture zone. This slip suddenly and permanently uplifted some areas of the seafloor and down-dropped others, causing corresponding vertical movement of the overlying water. Preliminary modeling by scientists at the University of California, Santa Barbara (UCSB), indicates that the March 11 earthquake may have raised parts of the seafloor as much as 9 m (30 ft). (See figure 5.1 at **http://www.geol.ucsb.edu/faculty/ji/big_earthquakes/2011/03/0311/Honshu.html**.) The tsunami was born as the energy of the displaced water moved away from the source in a series of waves. (For more information about how tsunamis form and move through the ocean, visit **http://walrus.wr.usgs.gov/tsunami/basics.html**.)

While the March 11 tsunami traveled throughout the Pacific Ocean basin, damaging harbors as far away as Crescent City and Santa Cruz, California, the most devastating effects were caused by the “local” tsunami, whose first crest may have reached Japan’s northeast coast as quickly as 10 minutes after the earthquake. This local tsunami was widely documented in

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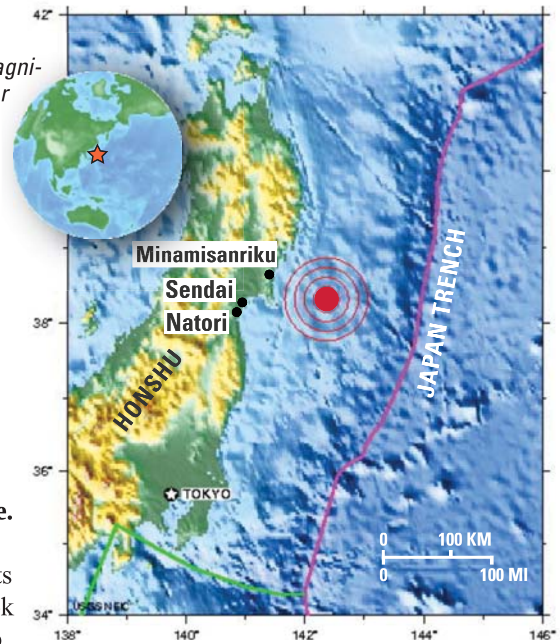
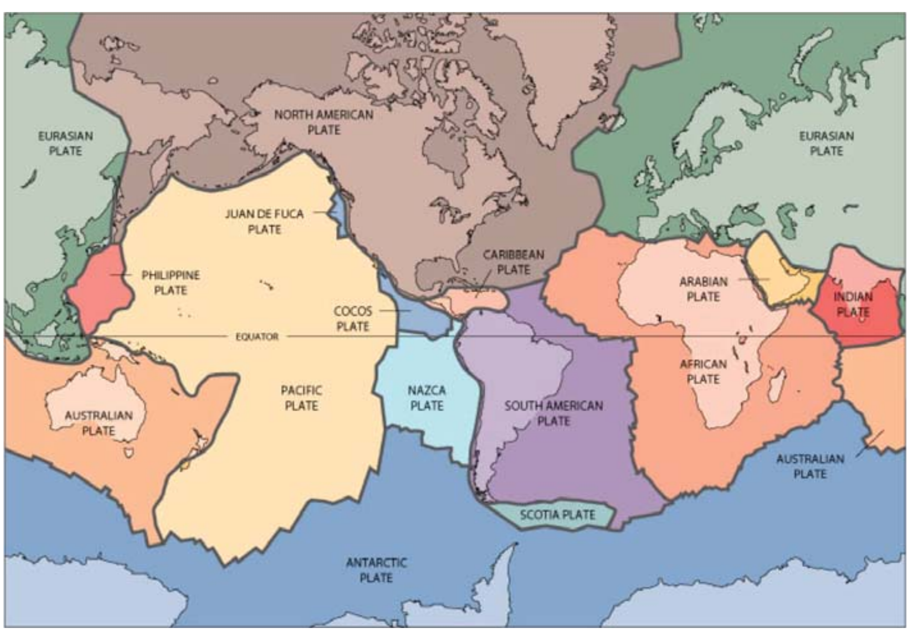
Location of the March 11, 2011, magnitude 9.0 earthquake epicenter (star on globe, red dot on map).





Generalized map of plate boundaries, from This Dynamic Earth: the Story of Plate Tectonics *(USGS, **http://pubs.usgs.gov/gip/dynamic/slabs.html**). Northern Japan sits on a part of the North American plate that is sometimes referred to as the Okhotsk microplate.*

Sound Waves

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Submission Guidelines

Deadline: The deadline for news items and publication lists for the June issue of *Sound Waves* is Thursday, April 14.
Publications: When new publications or products are released, please notify the editor with a full reference and a bulleted summary or description.
Images: Please submit all images at publication size (column, 2-column, or page width). Resolution of 200 to 300 dpi (dots per inch) is best. Adobe Illustrator© files or EPS files work well with vector files (such as graphs or diagrams). TIFF and JPEG files work well with raster files (photographs or rasterized vector files).

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Need to find natural-science data or information? Visit the USGS Frequently Asked Questions (FAQ's) at URL **http://www.usgs.gov/faq/**

Can't find the answer to your question on the Web? Call 1-888-ASK-USGS

Want to e-mail your question to the USGS? Send it to this address: ask@usgs.gov

Research, continued

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online videos that show dark water pushing through towns and over farmland, crushing buildings and carrying swirling masses of debris, including cars and houses. News accounts reported walls of water as high as 30 to 40 ft and waves that reached as far as 10 km (6 mi) inland. More precise measurements of inundation distances (the horizontal distance between the shoreline and the farthest point inland reached by the water) and runup heights (the difference between the ground elevation of the tsunami's farthest inland reach and sea level at the time of the tsunami) will be made when teams of scientists are able to conduct field surveys. Survey teams may be hard pressed to find structures on which to measure water levels because some coastal towns, such as Natori and Minamisanriku, were virtually obliterated by the tsunami. At this writing (March 15), the death toll is in the thousands and expected to rise.

Scientists are currently analyzing the wealth of data collected during the earthquake and tsunami, and their preliminary findings have shed some light on why the tsunami was so large. Several factors contributed to the tsunami's enormous size, including the magnitude, depth in the Earth's crust, and overlying water column of the triggering earthquake.

The March 11 earthquake "was one of the very largest earthquakes that we have ever recorded during the past hundred years of instrumental studies of earthquakes," according to **Ellsworth**. At magnitude 9.0, it is exceeded by only a few earthquakes, such as the 1964 Alaska earthquake. (See list of "Largest Earthquakes in the World Since 1900" at **http://earthquake.usgs.gov/earthquakes/world/10_largest_world.php**.) It was nearly as large as the magnitude 9.1 earthquake that struck Sumatra in 2004 and triggered the destructive Indian Ocean tsunami.

The depth of the earthquake in the Earth's crust also affects tsunami size. Preliminary estimates put the focus of the March 11 earthquake—the point where rupture began—approximately 24 km (15 mi) beneath the Earth's surface, making it a relatively "shallow" earthquake. (Subduction-zone earthquakes can occur as deep as 700 km below the Earth's surface.) The shallower the earthquake is in the Earth's crust, the more energy is transferred to the overlying water, and the larger the resulting tsunami.

The size of a tsunami is also determined by both the amount of elevation change on the seafloor and the depth of the overlying water column. As noted earlier, parts of the seafloor may have risen as much as 9 m (30 ft) during the March 11 earthquake. Preliminary modeling by UCSB scientists (**http://www.geol.ucsb.edu/faculty/ji/big_earthquakes/2011/03/0311_v3/Honshu.html**, fig. 4) indicates that the most extreme seafloor displacement during the March 11 earthquake occurred in fairly deep (approx 4,000 m) water. The deeper the water above the deformed seafloor, the greater the mass of displaced water and the larger the tsunami. (For a more detailed discussion of the effects

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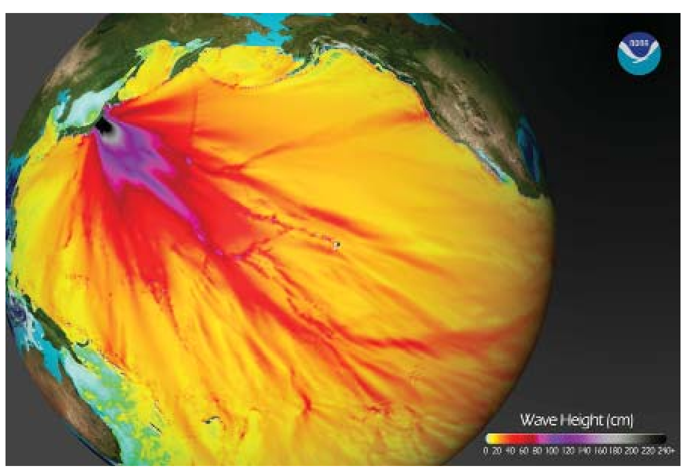

*Maximum forecast wave amplitudes for March 11, 2011, tsunami, computed with the MOST (Method of Splitting Tsunami) model. Note ray of tsunami energy refracted toward California and Oregon by seafloor topography. Image courtesy of the National Oceanic and Atmospheric Administration (NOAA) Center for Tsunami Research (**http://nctr.pmel.noaa.gov/**).*

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of rupture location on tsunami size, visit **http://soundwaves.usgs.gov/2010/04/research2.html** and scroll down to the paragraph beginning "Earthquakes with the same magnitude….")

Subduction-zone earthquakes, like the March 11 event, commonly cause simultaneous uplift of offshore regions and subsidence of coastal land. Coastal subsidence is another factor that field-survey teams will investigate; preliminary observations suggest that parts of the Japanese coast subsided more than half a meter (about 2 ft) during the March 11 earthquake, making these areas even more vulnerable to the subsequent tsunami.

Measurements by field-survey teams will add to those already available from seismographs, tide gauges, deep-ocean tsunami-monitoring systems, GPS (Geographic Positioning System) stations, and other sensors to produce a huge dataset that scientists will study to improve our understanding of earthquakes and tsunamis and help devise better ways to prepare for them. That Japan—arguably the best-prepared country in the world for earthquakes and tsunamis—has been hit so hard by the March 11 event is a harsh reminder of how much we still have to learn.

Visit **http://earthquake.usgs.gov/earthquakes/eqinthenews/2011/usc0001xgp/** for additional information about the earthquake. Visit **http://walrus.wr.usgs.gov/tsunami/sendai11/** to view computer animations of the tsunami hitting the east coast of Japan. Visit **http://walrus.wr.usgs.gov/news/field.html** to view photographs and preliminary observations of the effects of the tsunami in California and Hawaiʻi, plus links to Web sites with additional information and images. ❆

*Wave heights are highly exaggerated in these screen shots from computer animations of the tsunami generated by the March 11, 2011, magnitude 9.0 earthquake. View northward in top image, southward in bottom image. Visit **http://walrus.wr.usgs.gov/tsunami/sendai11/** to view the animations, created by USGS research geophysicist **Eric Geist**. A wave trough was the first part of the tsunami to reach the shore. Note the drawdown as water flows away from the shore while the first crest approaches. Vertical exaggeration is approximately 10:1 for features on the land (green) and sea-floor (blue); wave heights are greatly exaggerated with respect to topography for visualization purposes.*

Long-Lived, Slow-Growing Corals in Deep Waters of the Gulf of Mexico

By Nancy Prouty

In stark contrast to an earlier notion in the 1800s that life should not exist below 600 m in the ocean, deep-sea coral ecosystems are now widely recognized as biodiversity hotspots. Like shallow-water coral reefs, deep-sea coral-reef ecosystems are among the most diverse and productive communities on Earth, providing shelter and feeding grounds for both commercial and noncommercial fish species and their prey, as well as breeding and nursery areas. They also serve as a valuable hunting ground for new medicines; a source of human income and food from such commercially important fishes as rockfish, shrimp, and crab; and a window into past environmental conditions recorded in the chemistry of coral skeletons. Activities that affect the seafloor, such as certain methods of petroleum exploration and commercial fishing, can affect these ecosystems. A better understanding of the complexity and interconnectivity of deep-sea-coral ecosystems will help us better assess natural and human impacts, as well as decipher chemical records of past conditions.

*These 2- to 3-m-tall orange-colored black coral trees (*Leiopathes *cf.* glabberima*) growing near Viosca Knoll are among the oldest living organisms on Earth. (From USGS Open-File Report 2008-1148 by **Ken Sulak** and others, **http://fl.biology.usgs.gov/coastaleco/OFR_2008-1148_MMS_2008-015/stills.html**).*

To improve our understanding of deep-sea coral ecosystems, U.S. Geological Survey (USGS) scientists and their partners recently investigated the growth rates and ages of deep-sea black corals in the Gulf of Mexico. Their results were reported in the February 10 issue of *Marine Ecology Progress Series* (**http://www.int-res.com/journals/meps/meps-home/**).

This study confirms that black corals are the slowest-growing deep-sea corals

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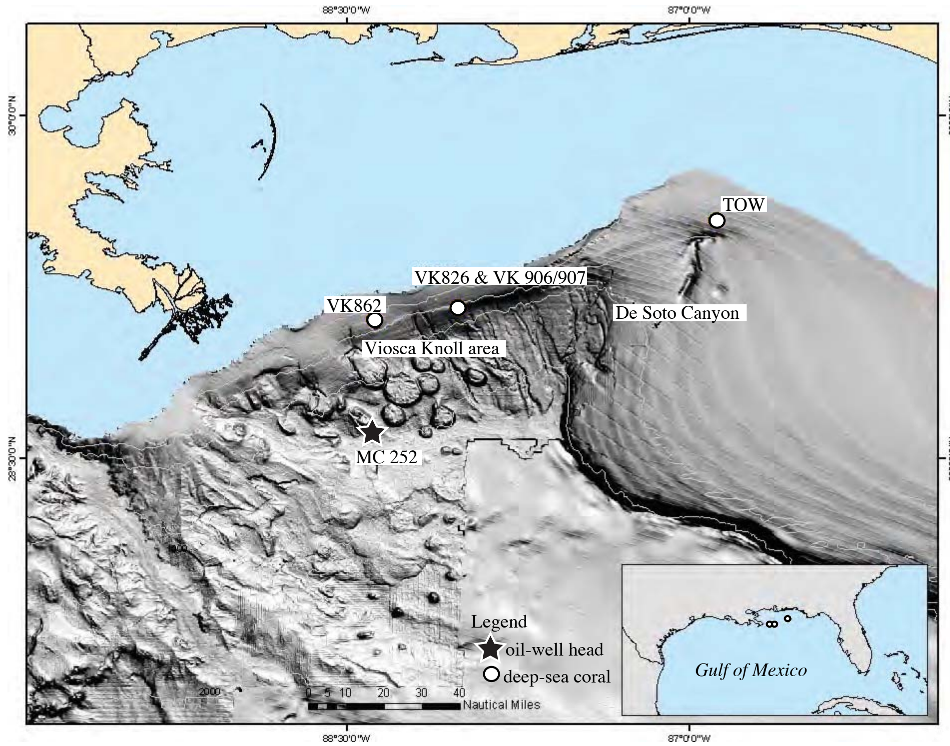
and are extremely long lived. The authors applied ^{14}C dating methods to black coral samples collected within 40 to 50 km north and northeast of the recent Deepwater Horizon oil spill and discovered that the sampled animals have been growing continuously for at least the past 2 millennia, with growth rates ranging from 8 to 22 micrometers (µm) per year. In comparison, the shallow-water coral *Porites lobata*, typically found in tropical areas like Hawai‘i, grows about 10 mm per year, or more than 600 times as fast as black coral; and human fingernails grow about 36 mm per year, or more than 2,000 times as fast as black coral. Like ancient solitary, old-growth forests on land, these slow-growing deep-sea coral communities may be easily disturbed and slow to recover.

The investigators detected the presence of bomb-derived ^{14}C (artificially produced by the detonation of nuclear test weapons in the atmosphere in the late 1950s and early 1960s) in the samples, confirming that black corals make their skeletons predominantly from particulate organic matter that sinks from the ocean surface, rather than from dissolved inorganic carbon in their deep-water surroundings. Thus, black corals can capture and record in their skeletons the history of changing concentrations of ^{14}C in surface waters and the atmosphere, despite living at water depths greater than 50 m.

Unlike the skeletons of most shallow-water corals, which consist of calcium carbonate ($CaCO_3$), black coral skeletons are composed mainly of organic matter: successive layers of protein and chitin (a long molecule containing carbon, oxygen, hydrogen, and nitrogen) glued together by a cement layer. These skeletons are very similar to insect cuticles in that they are quite flexible and can thus bend in water currents. The flexibility and shiny luster of black coral have made it a precious commodity in the coral jewelry trade. In fact, black corals have been harvested for centuries to create charms and medicines; the scientific name of the order to which black corals belong, “Antipatharia,” comes from Greek roots meaning “against suffering.”

Black corals grow in treelike or bushlike forms. Because they get their food from sinking organic matter instead of from symbiotic algae, like their shallow-water counterparts, black corals need skeletons that are flexible but strong enough to withstand currents that transport food to the colonies. In addition to a constant flow of water bringing them food and oxygen, the corals require a stable substrate, such as volcanic or calcareous rock, or even a shipwreck or oil rig that can serve as a platform for the corals to settle on and build their skeletons.



Deep-sea coral samples were collected between 2003 and 2009 from two sites on the upper De Soto Slope subprovince: the head of De Soto Canyon and Viosca Knoll (VK), including the BOEMRE lease blocks VK862 and VK 906/907. The Deepwater Horizon wellhead at the Mississippi Canyon MC252 lease block (star) and the VK826 site are also marked. Samples were collected at water depths of approximately 300 m by using both a trawl net (at site labeled TOW) and the manned submersible Johnson-Sea-Link *(all other sites).*

Like trees, black corals exhibit radial growth, with the oldest skeletal material in the center and successively younger material building out toward the edges. Viewed in a horizontal cross section, the black coral’s growth bands resemble tree rings. The recent study found a fairly good correlation between ages derived from ^{14}C analysis and visual counts of coral growth bands, indicating that each band represents a year of growth. Annual variations in food supply may be a factor affecting annual skeletal growth; however, the exact mechanism to explain the formation of annual growth bands remains unclear.

Reliably dating the corals, as done in the recent study, is a critical step in using them as natural archives of climate change. The skeletons that these animals secrete continuously over hundreds to thousands of years offer an unprecedented window into past environmental conditions. Dating used in combination with emerging technologies, such as sampling skeletal material onsite with a laser to determine its chemical composition, enables scientists to reconstruct environmental conditions in time slices smaller than a decade over the past 1 to 2 millennia. USGS scientists and their colleagues, for example, are measuring trace metals and stable isotopes in black coral skeletons that are related to nutrient supplies in surface waters, which, in turn, may reflect the amount of runoff from nearby land

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surfaces. With a proper understanding of how these chemical constituents vary over time, scientists can reconstruct a record of environmental changes, such as changes in land-based sources of nutrients and natu-

Sample of black coral (class Anthoza, order Antipatharia) collected from the Gulf of Mexico at 300-m depth, with a 15-cm ruler at base for scale.

ral variations in climate. This approach is similar to the use of chemical variations in sediment cores to reconstruct climate histories. However, whereas sedimentary records can be disrupted by low sedimentation rates and bioturbation (mixing by animals living in the sediment), records from coral skeletons are continuous and can be used to determine changes from centuries to millennia at time scales comparable to that of modern observations.

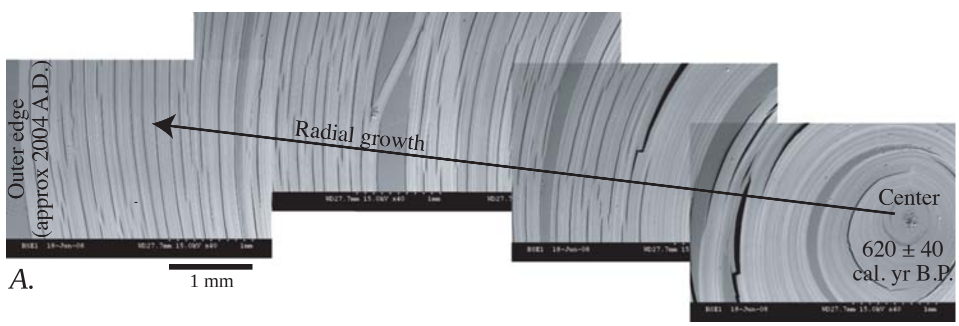
The recent study was part of the USGS Diversity, Systematics, and Connectivity of Vulnerable Reef Ecosystems (DISCOVRE) Expedition, in which USGS scientists are partnering with other Federal agencies, such as the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) and the National Oceanic and Atmospheric Administration (NOAA), as well as several academic institutions, to study deep-sea coral reefs. (See **http://soundwaves.usgs.gov/2009/12/fieldwork2.html** and **http://fl.biology.usgs.gov/DISCOVRE/**.) Experts from various fields among the Federal agencies and academic institutions are working together to try to understand the oceanography, biology, and ecology of these complex ecosystems. In doing so, they hope to decipher the degree to which geographically distinct communities share interconnected food chains and (or) are genetically related. Genetic diversity helps species adjust to changing conditions. If human or natural disturbances reduce the exchange of genetic traits between black coral communities, the older corals become more valuable as “banks” of genetic material for future populations. Overexploitation of black corals without proper management could easily lead to local population extinction. Given the extremely long life spans and very slow growth rates of black corals, it is unlikely that these species are renewable within the context of fishery management (2- to 3-decade time scale) or even within a human lifespan.

Cross-sectional disc of black coral skeleton (diameter, 2.4 cm).

The corals reported in this study were collected before the Deepwater Horizon oil spill from a study site later overshadowed by surface slicks; long-term monitoring may be required to assess potential damage from the spill. The USGS DISCOVRE team has conducted several research cruises since the Deepwater Horizon event to investigate its impacts (**http://fl.biology.usgs.gov/DISCOVRE/discovre_2010/discovre_10_oil_spill_update.html**).

The full citation for the new paper is:

Prouty, N.G., Roark, E.B., Buster, N.A., and Ross, S.W., 2011, Growth rate and age distribution of deep-sea black corals in the Gulf of Mexico: Marine Ecology Progress Series, v. 423, p. 101-115, doi:10.3354/meps08953 [**http://dx.doi.org/10.3354/meps08953**]. ❁



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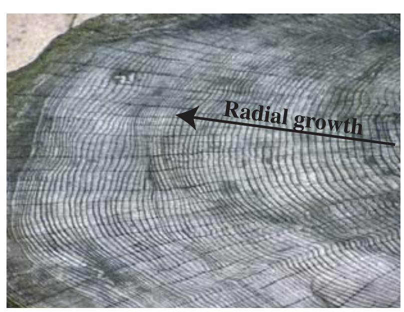

B.

A. Enlarged scanning electron microscope (SEM) image of a thin section from a black coral sample collected in the Gulf of Mexico. The oldest coral is at the center, its age estimated at 620 ± 40 calendar years before present. The outer edge represents coral growth at approximately the time of collection (A.D. 2004).
B. Tree rings, also referred to as growth rings, can be seen in this horizontal cross section through the trunk (1-m diameter) of an unknown tree species at Bristol Zoo, Bristol, England. Photograph by ***Adrian Pingstone****, September 2005 (****http://commons.wikimedia.org/wiki/File:Tree.ring.arp.jpg****).*

USGS Analyzing Sea Otter Death Data

By Ben Young Landis

Sea otter feeding on crab in Monterey Bay. Photograph by ***Tania Larson****, USGS, taken August 9, 2007.*

Southern sea otters (*Enhydra lutris nereis*) are on the federal threatened-species list, and their population growth has been puzzlingly sluggish and inconsistent (see "California Sea Otter Numbers Drop Again," *Sound Waves*, December 2010, **http://soundwaves.usgs.gov/2010/12/**). These furry predators remain an icon of the California coast, and so when word spreads about a record year for sea otter deaths, it quickly captures the public's attention.

In late January, researchers at the U.S. Geological Survey (USGS) Western Ecological Research Center (WERC) prepared a preliminary summary of sea otter deaths (called "strandings") observed in 2010, which showed a record number of 304 recovered otter carcasses. The data were shared with research colleagues and local stakeholders. (See tables in PDF format posted at **http://www.werc.usgs.gov/fileHandler.ashx?File=/outreachdocs/2011/2010 southern sea otter stranding summary_1.pdf**.)

"The USGS and its partners are currently analyzing the 2010 stranding data in the context of 25 years of sea otter observations in California," says **Tim Tinker**, lead scientist for sea otter research at WERC. The researchers expect to submit their findings for review and publication later this year.

USGS scientists normally prefer to carefully assess and compare new data before educating the public about overall results and implications. The 2010 preliminary data, however, do offer some hints about stranding trends:

- 304 strandings represent about 11 percent of the current population estimate, an increase from the 8 to 10 percent reported in the recent decade.
- 32 percent of recovered carcasses were of adult and subadult females—potential mothers—an increase from pre-2008 figures of 27 percent.
- Carcass necropsies revealed diseases from several chemical and biological factors, including toxins from inland lakes. (See related news release from the University of California, Santa Cruz, **http://news.ucsc.edu/2010/09/otter-toxin.html**.)
- 22 percent of recovered carcasses showed signs of fatal shark attack, up from pre-2000 figures of 10 percent. (See related news release from the California Department of Fish and Game, **http://www.dfg.ca.gov/news/news10/2010091501-Otter-Deaths-Rise.html**.)

Tim Tinker*, a research wildlife biologist with the USGS Western Ecological Research Center (WERC), leads the center's sea otter projects. He is also an adjunct professor in the Department of Ecology and Evolutionary Biology at the University of California, Santa Cruz. Photograph by* ***Paul Laustsen****, USGS, taken in August 2008.*

"Our past research indicates that only about half of sea otters that die in the wild are ever recovered, so a single year's numbers can't be considered an accurate or unbiased indicator of population mortality," says **Tinker**. "Nonetheless, the number of dead sea otters observed—relative to population estimates—has been elevated in recent years, so we're trying to discover why."

The California Sea Otter Stranding Network (visit **http://www.werc.usgs.gov/seaottercount** and click "Stranding Network" on left), which was implemented by the California Department of Fish and Game (CDFG; **http://www.dfg.ca.gov/**) in 1968, is currently overseen by the USGS with support from the CDFG. The purpose of this network is to verify all reports of stranded sea otters in California and to recover the carcasses whenever possible. The network is composed primarily of the USGS WERC; the CDFG Marine Wildlife Veterinary Care and Research Center (**http://www.dfg.ca.gov/ospr/Science/marine-wildlife-vetcare/**), which also conducts necropsies; the Monterey Bay Aquarium's Sea Otter Research and Conservation program (SORAC, **http://www.montereybayaquarium.org/cr/sorac.aspx**); the California Academy of Sciences (**http://www.calacademy.org/**);

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the Marine Mammal Center (**http://www.marinemammalcenter.org/**); and the Santa Barbara Museum of Natural History (**http://www.sbnature.org/**). Additional agencies and organizations also contribute stranding data and conduct studies of the southern sea otter population.

As part of the federal southern sea otter recovery and management plan, the USGS will once again conduct its annual sea otter population survey along the California coast in spring 2011 (visit **http://www.werc.usgs.gov/seaottercount** and click "Sea Otter Surveys"). An ongoing USGS-led study of radio-tagged sea otters in Monterey and Big Sur is comparing the health, behavior, diet, and survival rates of sea otters at these sites, to investigate the impacts of human stressors on sea otter populations. Also, USGS scientists in California, Washington, and Alaska are collaborating with state, federal and Canadian colleagues to study sea otters throughout the Pacific coast of North America. By comparing the coastal environments and sea otter health at these different locations, the USGS hopes to discern the health of our nearshore ecosystems (see *Sound Waves* article at **http://soundwaves.usgs.gov/2010/03/**) and any potential implications for our natural and economic resources.

For more information about WERC sea otter research, visit **http://www.werc.usgs.gov/seaottercount**.

***Note:** The original version of this article, with additional links, appeared January 24, 2011, on the USGS WERC Outreach Web page, **http://www.werc.usgs.gov/outreach.aspx**.*

CO2calc—a User-Friendly Seawater-Carbon Calculator for Windows, Mac OS X, and iOS (iPhone)—Will Assist Studies of Ocean Chemistry

By L.L. Robbins, USGS, and J.A. Kleypas, National Center for Atmospheric Research

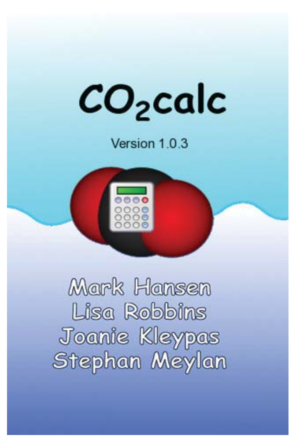
Research findings of the past decade have led to mounting concern that rising atmospheric carbon dioxide (CO_2) concentrations will cause changes in the ocean's carbonate chemistry system, and that those changes will affect some of the most fundamental biological and geochemical processes of the sea.

—Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers
(http://www.ucar.edu/news/releases/2006/report.shtml)

Currently, the ocean absorbs about 30 percent of the carbon dioxide (CO_2) released to the atmosphere by fossil-fuel combustion. As the atmospheric concentration of CO_2 rises, so does absorption of CO_2 by the ocean, causing chemical changes that include a decrease in seawater pH. This "ocean acidification" reduces the availability of carbonate ions (CO_3^{2-}) required for building the shells and skeletons of calcifying marine organisms. Such changes, which could have far-reaching effects, have intensified researchers' interest in the study of seawater carbon—particularly CO_2 and other forms of inorganic carbon—and the need for tools to gather and manage increasing amounts of chemical data.

Since the late 1990s, those who conduct research on the chemical behavior of inorganic carbon in seawater have had several software packages for calculating CO_2-system chemistry. **Ernie Lewis** of the Brookhaven National Laboratory and **Doug Wallace** of the Leibniz Institute of Marine Sciences at Kiel University (Germany) first undertook the monumental effort of sorting through the original literature and equations to produce CO2SYS, a Windows-based program that has been an invaluable and well-documented service to the research community (see **http://cdiac.ornl.gov/oceans/co2rprt.html**). The equations and documentation of CO2SYS have since been adapted for use within Microsoft Excel and coded for use within such programming languages as MatLab and "R" (for example, see **http://CRAN.R-project.org/package=seacarb**). These programs are not particularly user friendly, however, and in some cases require users to have a fair amount of skill in a computer language.

While walking with our iPhones at the Ocean Carbon Biogeochemistry Short Course on Ocean Acidification in November 2009, we decided that an iPhone application (app) for CO2SYS would be a valuable tool for many researchers, particularly for new students in the field. Development of this app would also enable the more rapid analysis of carbon data from two USGS projects: the Response of Florida Shelf Ecosystems to Climate Change project (**http://coastal.er.usgs.gov/flash/**) and the new Arctic Ocean Acidification project (**http://coastal.er.usgs.gov/ocean-acidification/polar.html**).



Opening page on the CO2calc iPhone app.

With the excellent programming skills of **Mark Hansen** (USGS, St. Petersburg, Florida) and **Stephan Meylan** (Jacobs Technology, contracted to the USGS), we developed CO2calc, an easy-to-use CO_2-system calculator designed for anyone with a PC, Mac, or iPhone. The app is described in USGS Open-File Report 2010-1280 (**http://pubs.usgs.gov/of/2010/1280/**).

Like the other calculators, CO2calc is based largely on CO2SYS, but it incorporates several new developments in CO_2-system calculations, including op-

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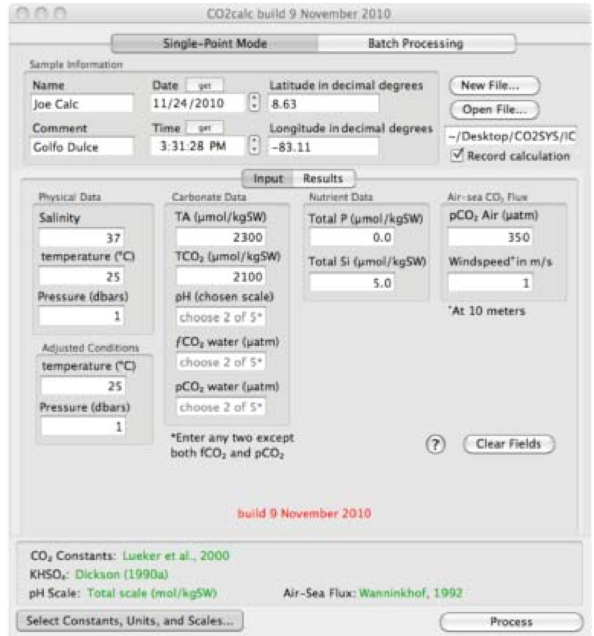
(CO2calc continued from page 7)

tions to use the dissociation constants of **Tim Lueker** and others (**http://dx.doi.org/10.1016/S0304-4203(00)00022-0**), as well as the constants of **Frank Millero** (**http://dx.doi.org/10.1071/MF09254**), which are a better fit for estuarine waters. An entirely new feature is the option to calculate air-sea CO_2 fluxes according to the gas-transfer-velocity formulations of **Rik Wanninkhof** (**http://dx.doi.org/10.1029/92JC00188**), **Philip Nightingale** and others (**http://dx.doi.org/10.1029/1999GB900091**), and **David Ho** and others (**http://dx.doi.org/10.1029/2006GL026817**). This last feature has enabled a rapid, more comprehensive approach to analyzing USGS CO_2 flux data from the west Florida shelf and the Arctic. Currently, USGS scientists and collaborators are using the app to develop carbon budgets in the Gulf of Mexico.

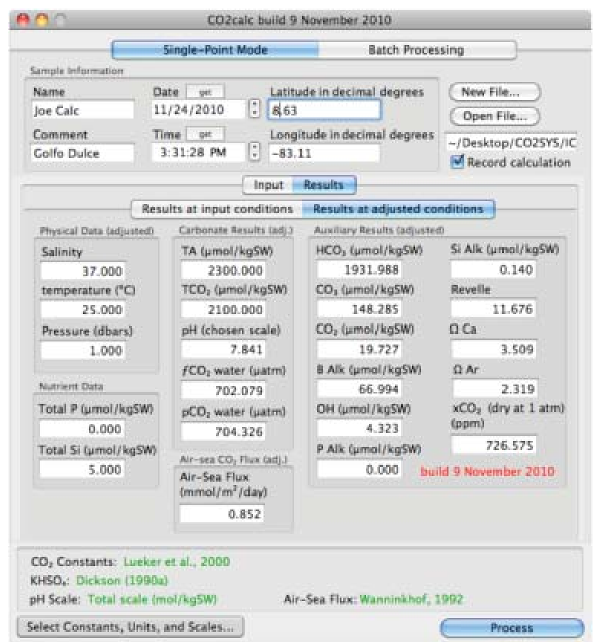
CO2calc has an intuitively designed graphical user interface for choosing constants, entering data, and displaying results. It also includes many additional features, such as the capability of tagging data with date, time, latitude/longitude (all of which can be automatically retrieved on iPhone 3, 3GS, 4, and Windows hosts that have an NMEA [National Marine Electronics Association]-enabled GPS), as well as sample name and comments. It also allows batch-file processing, as well as an option to save sample information, data input, and calculated results as a comma-separated value (CSV) file for use with Microsoft Excel, ArcGIS, or other applications. Finally, it includes an option to export points with geographic coordinates as a KMZ file for viewing and editing in Google Earth. CO2calc documentation is provided as a PDF file, which on the iPhone version is organized into separate tab-based folders. CO2calc versions for Mac, PC, and iPhone can be downloaded from the USGS Web site at **http://pubs.usgs.gov/of/2010/1280/** and from the Carbon Dioxide Information Analysis Center (CDIAC) Web site at **http://cdiac.ornl.gov/oceans/datmet.html**, which offers the other CO_2-system calculation programs as well. The iPhone version is also available for free in the Education section of the iTunes App store.

An important lesson learned during the development of CO2calc is that the small format of the iPhone forced the design of the interface to be simple and intuitive, so much so that the format was adapted for the PC and Mac interfaces. This new application is not only novel but also very handy for both inexperienced and experienced researchers. Since the launch of CO2calc in mid-December, we have received positive feedback from educators and scientists in many countries who are or will be using it in their classes and research. Statistics from the USGS publication site and iPhone App store indicate that researchers in more than 17 countries have already downloaded this app, either for Mac, PC, or iPhone.

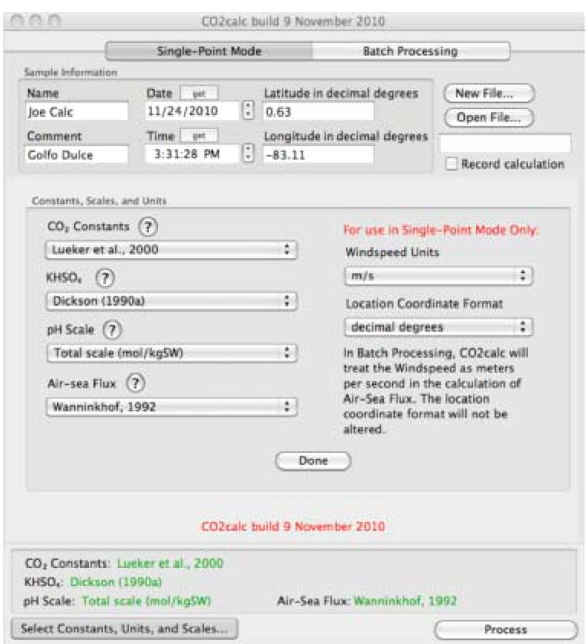
Note: *A similar version of this article, with a complete list of technical references, was published in the January 2011 issue of* SOLAS News, ***http://www.solas-int.org/news/newsletter/newsletter.html.***



CO2calc display for entering data.



CO2calc display for displaying results.



CO2calc display for selecting constants.

Message in a Saucer—USGS Drifter Lands on Vancouver Island, Canada, 40 Years After Release

By Laura Judson, Parks Canada

Like a message in a bottle, a yellow disk recently washed up on the shores of Long Beach in Vancouver Island's Pacific Rim National Park Reserve, leading Parks Canada staff to uncover a decades-old story that began near San Francisco's Golden Gate Bridge.

This fall, a visitor found a yellow plastic saucer-shaped disk on Long Beach and left it against a recycling bin. When Parks Canada janitor **Jackie Aubertin** found it, she was curious about the disk and took it back to the office to clean it up. As she scrubbed, a message was slowly revealed:

50 CENT REWARD ON RETURN OF SERIAL NUMBER WITH DATE FOUND, LOCATION, YOUR NAME, YOUR ADDRESS TO MARINE GEOLOGY - U.S. GEOL. SURVEY, 345 MIDDLEFIELD, MENLO PARK, CA 94025

Jackie brought the strange find to ecosystem scientist **John McIntosh**, who followed the instructions on the disk and sent it back to Menlo Park, California, offering to forego the 50-cent reward in the interest of science. While we waited for a reply, the mystery of the yellow disk became a bit of a joke among the staff. **Jackie** was even presented with a thank-you letter, allegedly from U.S. President Obama, with two American quarters attached.

In December, the disk's real history came to light: a letter arrived from **Laura Torresan**, webmaster for the U.S. Geological Survey (USGS) Pacific Coastal and Marine Science Center, expressing excitement about the find. The letter explained that the disk was actually part of a seabed drifter, a yellow disk with a weighted tail to minimize the influence of factors other than bottom currents. Our seabed drifter had been dropped off near the Golden Gate Bridge 40 years ago as part of a study on bottom currents. It took a combination of currents from 1970 until 2010 to get the disk (now minus its weighted tail) from the Golden Gate Bridge to the Clayoquot Sound area. It appears to be one of the last stragglers from a total of nearly 8,000 near-bottom drifters that were released over a year as part of a study of water circulation in the San Francisco Bay area. Staff at the USGS sent some baseball caps along with a kind letter thanking Parks Canada staff for stirring up memories of the "good ol' days."

Word of the yellow disk also spread to one of the original researchers, now-

(Drifter Found in Canada continued on page 10)

*Although Long Beach on Vancouver Island is about 1,300 km (800 mi) from San Francisco Bay as the crow flies, the drifter likely traveled many times that distance. USGS emeritus scientist **David Peterson**, who took part in the original study, notes that ocean currents reverse seasonally on the west coast, and speculates that the disk traveled to and fro for years before finally washing up on Long Beach. (Enlarged map of Vancouver Island modified from Parks Canada map at **http://www.pc.gc.ca/pn-np/bc/pacificrim/visit/visit12/a.aspx**; used with permission.)*

*Disk found by Parks Canada janitor **Jackie Aubertin** beside a recycling bin on Vancouver Island. When originally deployed near San Francisco, California, it had a red plastic stem with a brass weight near the end. A similar drifter, complete with stem and weight, was recovered in 2007 in San Pablo Bay, California, much closer to its original starting point (**http://soundwaves.usgs.gov/2007/06/outreach.html**).*

(Drifter Found in Canada continued from page 9)

retired USGS emeritus scientist **David Peterson**. He was delighted by the find and sent along a report about the original study for which the disks were used to compile data. The discovery even landed on the front page of the *Victoria Times-Colonist* newspaper and was picked up by several other newspapers across Canada.

Now that its story has been told, the yellow disk is sitting in a designated bin in a USGS archive, its long 40-year journey finally complete, thanks to the curiosity of **Jackie** and **John**.

***About the author: Laura Judson** is a Public Relations and Communications Officer with the Coastal British Columbia Field Unit of Parks Canada.*

*Parks Canada janitor **Jackie Aubertin** (left) holds a thank-you letter from the USGS, and ecosystem scientist **John McIntosh** holds a 1970 report (USGS Circular 637-A, B; **http://pubs.er.usgs.gov/publication/cir637AB**) about the San Francisco Bay water-circulation study that launched the yellow drifters. (Another report was published in 1971: "Drift of Surface and Near-Bottom Waters of the San Francisco Bay System: March 1970 through April 1971," USGS Miscellaneous Field Studies Map MF-333, **http://pubs.er.usgs.gov/publication/mf333**.)*

Linking Marine Aquariums to Marine Research and Conservation

By Matthew Cimitile

Seeking to find new, creative ways to communicate and educate the public and our partners on U.S. Geological Survey (USGS) research, the USGS St. Petersburg Coastal and Marine Science Center has partnered with the Pier Aquarium in downtown St. Petersburg, Florida, to create a distinctive aquatic display of a mangrove ecosystem with Caribbean corals. Stocked and maintained by Pier Aquarium personnel and located at the USGS center, the display is designed to complement ongoing USGS research.

The goal is to create a setting that resembles the unique coral-mangrove environment found in an area of St. Johns Virgin Islands National Park called Hurricane Hole (see related article in *Sound Waves*, April 2010, **http://soundwaves.usgs.gov/2010/04/**). At Hurricane Hole, a highly diverse, colorful array of corals was recently discovered living among mangrove roots in the shade of red mangrove trees.

*(Left to right) Pier Aquarium's Curator of Exhibits **Butch Ringelspaugh**, Public Relations and Marketing Intern **Andrea Inman**, President and CEO **E. Howard Rutherford**, and Public Relations and Marketing Director **Emily Stehle** stand with USGS Journalist/Communications Specialist **Matthew Cimitile** in front of the newly established aquarium in the USGS center's lobby.*

The new partnership grew out of discussions between USGS Information Specialist **Ann Tihansky** and Pier Aquarium Curator of Exhibits **Butch Ringelspaugh** about producing and maintaining an aquatic display that would showcase the local marine life of south Florida and the greater Caribbean. **Ringelspaugh** was inspired by research on the unique environment at Hurricane Hole to expand on the local feel and replicate a coral-mangrove ecosystem at the USGS center.

"I had read about the research involving corals living among mangroves in Hurricane Hole in St. Johns in science journals and in *Sound Waves*, and I figured it would be perfect to try to replicate that environment as a great teaching tool to highlight what the USGS does," said **Ringelspaugh**. "Using a mangrove to display a coral-reef

(Marine Aquariums continued on page 11)

(Marine Aquariums continued from page 10)

habitat is unheard of and would be a one-of-a-kind aquarium."

Ringelspaugh's first step was to establish a stable environment and good water quality before introducing fish and creating the coral-mangrove setting. To create a suitable environment, he applied the Pier Aquarium's natural filtration method of utilizing microorganisms that inhabit deep sand beds and porous rock (called "live rock" because of its tiny inhabitants) to filter out ammonia and nitrate from the water. The mangrove roots also filtered water by pulling out nitrogen and phosphate. The tank was then allowed to cycle the water for a few weeks, allowing bacteria and other parameters to reach equilibrium suitable for marine organisms to thrive.

A sergeant major fish (type of damselfish) swims by an assortment of live rock, sea anemones, sea urchins, and sponges within the mangrove-ecosystem aquarium at the USGS St. Petersburg Coastal and Marine Science Center.

Currently, a red mangrove tree grows out of the center of the open tank. A vibrant marine ecosystem of damselfish, Spanish hogfish, sea urchins, starfish, hermit crabs, horseshoe crabs, sea anemones, feather duster worms, and several species of sponge make their homes below and among the mangrove roots, which are firmly established in the thick sand. The next step is to introduce coral species, such as those found at Hurricane Hole, hoping they will settle in among the mangrove roots. This gives the Pier Aquarium the opportunity to expand on skills in designing, establishing, and managing aquariums of unique marine environments.

Red mangrove roots are firmly established in the thick sand bed, where they filter out nitrogen and phosphate. Corals will soon be introduced in the hope that they will settle among the mangrove roots.

An aquarium can be a useful communication and education tool to highlight the complexity and beauty of marine environments; it can fascinate viewers and stimulate discussion on current marine issues. "Seeing a sea cucumber or a hermit crab feed for the first time can spur interest and make people want to find out more about coastal and marine science," said **Tihansky**. "If you don't snorkel and put your head in the water, you have no idea of the complexity of the marine environment that's around you every day. This is a living laboratory, and as a scientific organization we are grateful we can provide a platform that communicates research and helps educate the public on marine issues."

As an exhibit curator, **Ringelspaugh** plans to create additional aquariums with an educational focus to teach the public about marine science and conservation. "Highlighting research, technology, and conservation-based issues within the exhibit is a great way to grab someone's attention and start them thinking about problems, issues, and solutions," said **Ringelspaugh**.

The coral-mangrove aquarium project began almost a year ago. Since then, Pier Aquarium personnel have been common fixtures at the USGS center as they maintain the tank and participate in our annual Open House. At this year's annual event, they spoke to visitors about the ecosystem within the aquarium and what it takes to establish a working community of fish, sponges, and other saltwater marine life.

"Projects like these strengthen relationships between the Pier Aquarium and the rest of the marine-science community in Tampa Bay," said **E. Howard Rutherford**, President and CEO of the Pier Aquarium. "Our vision is that this live exhibit will complement ongoing research. It's a wonderful example of what the USGS is doing, and a great visual display of the environment in which research is taking place."❆

***Ringelspaugh** checks the health of mangroves under the metal halide aquarium lighting that provides photosynthetic radiation for the trees to grow.*

Boston University Marine Program Students Visit the USGS Woods Hole Coastal and Marine Science Center

By Seth Ackerman

On October 12, 2010, a group of undergraduate students in the Boston University Marine Program (BUMP) visited the U.S. Geological Survey (USGS) and the Woods Hole Oceanographic Institution (WHOI) in Woods Hole, Massachusetts. The BUMP students were part of a Marine Geographic Information Science course taught by **Kerry Lagueux**, geographic-information-systems (GIS) analyst and associate scientist at the New England Aquarium.

Chris Polloni (USGS), **Seth Ackerman** (USGS), **Scott Gallager** (WHOI), and **Karen Bolles** (Advanced Habitat Imaging Consortium) treated the visitors to a series of brief talks during the morning session. **Polloni** and **Ackerman** summarized research activities conducted at the USGS Woods Hole Coastal and Marine Science Center and discussed techniques, technologies, and results from the Massachusetts Seafloor Mapping Cooperative (**http://woodshole.er.usgs.gov/project-pages/coastal_mass/**). **Gallager** and **Bolles** discussed their work with the Habitat Camera Mapping System (HabCam) group at WHOI and offered a fascinating perspective of seafloor habitats as revealed through stunning photographs captured by their towed camera system (**http://habcam.whoi.edu/**).

Boston University Marine Program (BUMP) students from the 2010 Marine GIS course with the Alvin *submersible, instructor **Kerry Lagueux** (far right), and our WHOI tour guide **Hovey Clifford** (far-left top row).*

Some of the BUMP students were scheduled to sail on the SSV Corwith Cramer*, which they saw at a nearby dock during their tour. Photograph by **Edward Quanstrom**, April 2006 (**http://en.wikipedia.org/wiki/File:CorwithCramer.jpg**).*

After the morning talks, we visited the Computerized Scanning and Imaging (CSI) Facility at WHOI, run by **Darlene Ketten**. **Scott Cramer** and **Julie Arruda**, both of WHOI, gave us a tour of the facility, which included the computerized tomography (CT) scanning room; the necropsy lab, which was being cleaned up after the necropsy of a marine mammal; and a quick peek into the necropsy lab's storage freezer.

In the afternoon, we enjoyed a captivating tour of the WHOI dock and ocean engineering facilities by retired WHOI researcher **Hovey Clifford**. **Clifford** topped off the tour by surprising the group with an up-close and personal visit with *Alvin*, WHOI's deep submergence vehicle, which was making a rare visit back to Woods Hole.

A handful of the students were equally excited to spot the Sea Education Association's sailing ship vessel (SSV) *Corwith Cramer* docked nearby. The tall ship was stocking up for a trip to the Caribbean, where some of the awestruck BUMP students would meet it for a voyage from St. Croix, U.S. Virgin Islands, to Key West, Florida, as the final short course of their Marine Semester.

Special thanks are due to **Joanne Tromp** (WHOI) for helping to organize the WHOI lab and dock tours, and to **Chris Polloni** for organizing the USGS activities.

South Bay Science Symposium: Research on the Restoration of Salt Ponds in South San Francisco Bay

By Helen Gibbons

Scientists met with each other and the public in February to share research on restoring salt ponds to natural tidal wetlands in South San Francisco Bay, California. The South Bay Science Symposium was held at the U.S. Geological Survey (USGS) campus in Menlo Park, California, on February 3, 2011. The USGS is a major player in a partnership of federal, state, and nonprofit organizations working to restore 15,100 acres of industrial salt ponds to a mix of natural tidal marsh, mudflat, and other wetland habitats by about 2058. This project, called the South Bay Salt Pond Restoration Project, is the largest tidal-wetland-restoration project on the U.S. west coast.

The February 3 meeting was the third in a series of science symposia held every couple of years to update the public on the project and the scientific research being conducted to guide it. Executive Project Manager **John Bourgeois** opened the meeting by describing some of the salt ponds that have already been breached and exposed to tides, noting, "I think we all love to see these levees come down and these breaches happen and new habitat being restored, but it can't happen without good science, and that's why we're here today."

Science is a critical component of the "adaptive management" being used to implement the project. The term refers to an iterative process of decision making in the face of uncertainty: decisions are made, their effects studied, and the findings used to guide subsequent decisions. **Bourgeois** said, "Other large-scale restoration projects across the country have talked about adaptive management, [but] we're actually doing it. We have an extensive science program targeted for specific questions that can inform future phases of restoration."

*Forster's tern chick. South Bay sediment contains mercury as a result of historical mining. USGS research wildlife biologist **Josh Ackerman** and supervisory research ecologist **Collin Eagles-Smith** are studying the impact of mercury on Forster's tern eggs and embryos. (Read related article at USGS Western Ecological Research Center Web site, **http://www.werc.usgs.gov/outreach.aspx?RecordID=10**.) Photograph copyright **Michael Kern** and the Gardens of Eden (**http://www.thegardensofeden.org/**); used with permission.*

*Executive Project Manager **John Bourgeois** opens the South Bay Science Symposium on February 3, 2011. Photograph by **Doug Cordell**, U.S. Fish and Wildlife Service.*

San Francisco Bay has lost an estimated 85 percent of its historical wetlands to fill or alteration. This drastic decline in tidal-marsh habitats has decreased water quality, increased flood risks, and reduced populations of fish and wildlife that depend on tidal marshes. Restoration of the South Bay salt ponds—purchased in 2003 from Cargill, Inc. by state and federal agencies—will begin to reverse these trends and improve the overall health of San Francisco Bay. The goals of the project are to:

- restore and enhance a mix of wetland habitats,
- provide wildlife-oriented public access and recreation, and
- provide for flood management in the South Bay.

Bourgeois was followed at the podium by USGS scientist **Laura Valoppi**, Lead Scientist of the South Bay Salt Pond Restoration Project. **Valoppi** told the audience: "Part of the story that you'll hear today is that we're restoring areas; and, quite quickly, vegetation is coming in, fish

(South Bay Symposium continued on page 14)

(South Bay Symposium continued from page 13)

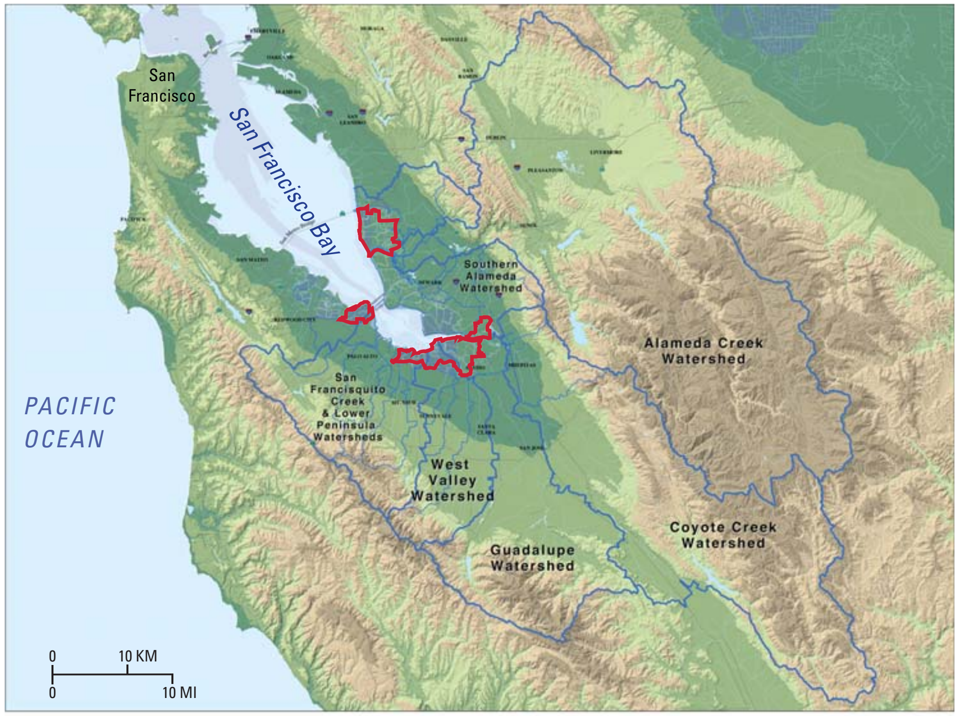
are coming in and using these restored areas, birds are coming in and using them…. So we are changing the ecosystem in the South Bay for the better, and it's an exciting time to be here." She outlined some of the key uncertainties being faced in this early phase of the project, which were the focus of many of the scientific talks that followed.

USGS scientists **Greg Shellenbarger** (research hydrologist, Sacramento, California) and **Bruce Jaffe** (research oceanographer, Santa Cruz, California) discussed physical processes and South Bay sediment—the "ground floor for our marsh" according to **Valoppi**, who had observed that "if we don't have sediment coming in to fill these ponds, we won't have a marsh."

USGS scientists **Jan Thompson** (research biologist, Menlo Park, California) and **Isa Woo** (biologist, Vallejo, California) reported on their studies of benthic invertebrates, such as clams and worms, that live in the bay-floor sediment and how their communities vary with time of year and bay-floor elevation.

*A full house. Photograph by **Ben Young Landis**, USGS.*

USGS wildlife biologists **Arriana Brand** (Vallejo) and **Mark Herzog** (Davis, California) described shorebird and duck responses to pond management (**Brand**) and the reproductive ecology of shorebirds (**Herzog**). Breeding populations of waterbirds currently make heavy use of salt-pond habitats in the South Bay. One goal of the South Bay Salt Pond Restoration Project is to restore a mix of habitats so that the needs of marsh species are balanced with those of populations that have come to rely on the salt ponds.



*Southern San Francisco Bay, showing South Bay Salt Pond Restoration Project boundaries (red outlines). Generalized from Watershed Map (Sept. 16, 2004) at **http://www.southbayrestoration.org/maps/#watershed**.*

USGS scientists **Mark Marvin-DiPasquale** (microbiologist, Menlo Park) and **John Takekawa** (research wildlife biologist, Vallejo) discussed the effects of wetland restoration on mercury bioaccumulation (**Marvin-DiPasquale**) and the effects of sea-level rise on salt marshes and endemic wildlife (**Takekawa**)—two of several challenges to marsh restoration identified by **Valoppi** in her introductory remarks.

After the speakers had concluded, **Valoppi** acknowledged that "much of the data that we've collected so far really was our sort of 'before' picture, before a lot of the main breaches." She added: "We're understanding how complex the ecosystem is. It shows that we need to continue to study these areas, especially in these first early phases of restoration, so we can form subsequent phases with good scientific data."

Additional speakers from other agencies, organizations, and universities addressed the meeting, and numerous USGS and other participants displayed posters during the lunch break and at an evening reception. Visit **http://www.southbayrestoration.org/science/2011symposium/** to download the meeting agenda and abstracts and to view video archives of the talks; visit **http://www.southbayrestoration.org/** for updates about this ongoing project.

*After the talks, panelists discussed scientific research conducted to guide salt-pond restoration: (left to right) **Mark Marvin-DiPasquale** (USGS), **Peggy Olofson** (Director, San Francisco Estuary Invasive Spartina Project), **John Takekawa** (USGS), and **Cheryl Strong** (U.S. Fish and Wildlife Service).*

Staff and Center News

New Intern from Sweden Assisting USGS Staff in Florida

By Gordon Anderson, Karen Balentine, and Tom Smith

A new intern from Sweden, **Marie Andersson,** is assisting **Gordon Anderson** and **Karen Balentine** with the U.S. Geological Survey (USGS) Southeast Ecological Science Center (SESC) Dynamics of Land Margin Ecosystems project led by **Thomas J. Smith III**. **Andersson** is based at the Daniel Beard Center in Everglades National Park. The USGS works cooperatively through the National Park Service International Volunteers in Parks (IVIP) Program to facilitate international student exchange in National Parks. **Andersson** recently received her Master's degree in Ecology and the Environment from Linköping University, Sweden; her thesis is titled "Oak (*Quercus robur* L.) Mortality in Southeastern Sweden: Influence of Weather and Environmental Variables." During **Andersson's** 5-month stay, she will primarily be studying mangrove ecology. Her email address is **marie.h.andersson@gmail.com**.

***Tom's** team (left to right)—**Karen Balentine, Marie Andersson**, and **Gordon Anderson**.*

To learn more about the Dynamics of Land Margin Ecosystems project, visit **http://sofia.usgs.gov/projects/index.php?project_url=dyn_margin**; to learn more about the National Park Service IVIP Program, visit **http://www.nps.gov/oia/topics/ivip/ivip.htm**.

Publications

Online Guide Now Available for Diatoms of the United States

For the first time, an online guide to diatoms of the United States (**http://westerndiatoms.colorado.edu/**) is available, including readily accessible images for identification.

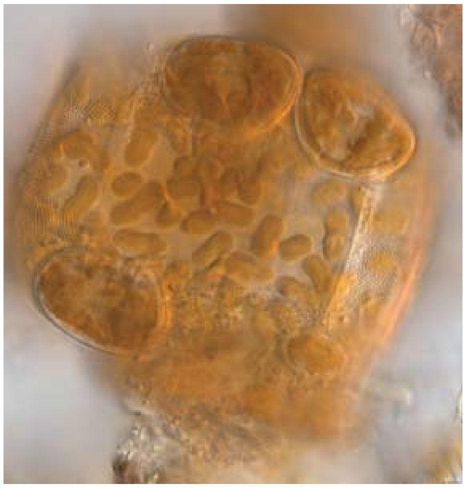
Diatoms are algae that reflect the biotic condition of streams, lakes, and estuaries. They are important indicator organisms because they are sensitive to natural and human impacts, and monitoring their condition provides information about ecosystem health. Together with aquatic invertebrates and fish, diatoms are included in federal and state monitoring and assessment programs as key indicators of biotic conditions.

"To date, taxonomic and ecological research on North American diatoms has been incomplete or outdated, constraining the ability of federal and state agencies to consistently assess the biological condition of aquatic ecosystems," said **Sarah Spaulding**, U.S. Geological Survey (USGS) ecologist and creator of the site. "As species pages are added, the online tool will promote taxonomic consistency and serve as the primary ecological resource on diatom biodiversity for the nation."

The online guide was developed with support from the USGS National Water-Quality Assessment (NAWQA) Program, the U.S. Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP), and EPA's National Aquatic Resource Surveys (NARS). The guide is targeted toward laboratory analysts, taxonomists, ecologists, students, water-resource managers, and the public.

The new guide integrates taxonomic, distributional, and ecological information, as well as images of diatom species of the United States from datasets derived from the NAWQA, EMAP, and NARS programs. Individual species pages are prepared by using a standard data-aggregation procedure and are peer-reviewed by recog-

(Online Diatom Guide continued on page 16)



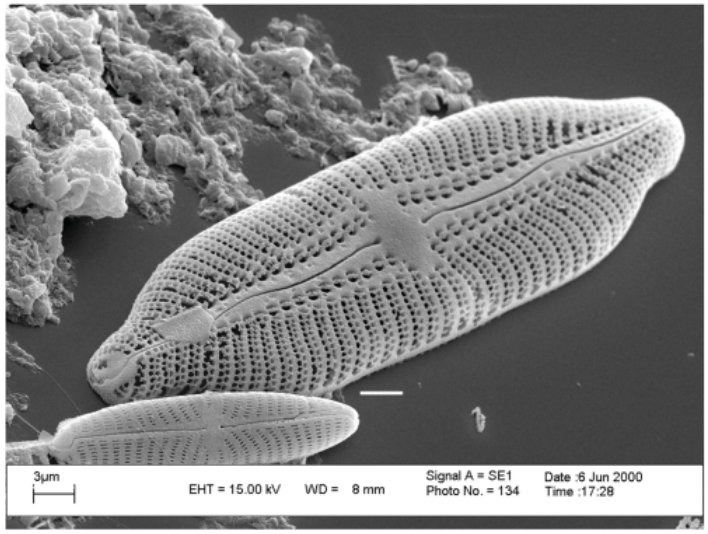
Large, living cell of the diatom Pleurosira laevis *has many disc-shaped chloroplasts (specialized subunits that perform photosynthesis). Three cells of the diatom genus* Cocconeis *are growing attached to the exterior of the* P. laevis *cell. Photograph by **Sarah Spaulding**.*

(Online Diatom Guide continued from page 15)

nized experts in diatom taxonomy. Species are grouped by genus and common morphological type, providing user flexibility, especially for nonspecialists, in making identifications through a visual key.

A total of 178 diatom taxa were available as of January 25, 2011; an additional 200 taxa are planned for inclusion by the end of 2011.

To learn more about the usefulness of diatoms, look at another new USGS product: "Environmental Investigations Using Diatom Microfossils," USGS Fact Sheet 2010-3115, by Kathryn E.L. Smith and James G. Flocks (**http://pubs.usgs.gov/fs/2010/3115/**).



Scanning electron micrograph shows one valve (shell) of an unusual species within the diatom genus Aneumastus*. This species is not typical of the genus, and its relation to other members of the group is poorly known. Photograph by* ***Sarah Spaulding****.*

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